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[54] **FLOTATION OF COARSE PARTICLES**

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[51] **Int. Cl.** **B03d 1/02**

[58] **Field of Search**.....209/158–161, 164, 166, 168, 170

[56] **References Cited**

UNITED STATES PATENTS

2,931,502	4/1960	Schoeld et al.	209/170 X
1,410,152	3/1922	Allen	209/160
2,783,884	3/1957	Schaub	209/165
1,167,835	1/1916	Norris	209/170
1,223,033	4/1917	Cole	209/170 X
2,758,714	8/1956	Hollingsworth	209/168
3,016,143	1/1962	Trachta	209/166
3,254,762	6/1966	Smith	209/166 X
3,298,519	1/1967	Hollingsworth	209/170 X

FOREIGN PATENTS OR APPLICATIONS

22,217	1895	Great Britain	209/160

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[57] **ABSTRACT**

Flotation of coarse particles of ore, particularly sylvinite ore, by passing concentrated conditioned pulp (about 60–70 percent solids) to top of cell just below overflow level, and passing a mixture of air and liquid into bottom of cell to float coarse particles, there being minimal turbulence but sufficient air bubbles for efficient flotation. Suitable apparatus is also provided comprising the flotation of coarse particles, said apparatus comprising a vertical tank, said tank being provided with discharge means, means for the overflow of floated particles suspended in carrier fluid, pulp feeding means at the upper portion of said tank terminating at a level below said means for the overflow, and at the lower portion of said tank means, fixed means for introducing a carrier fluid, and adjacent to said fixed means, fixed dispersing means for the introduction of a supplementary quantity of carrier fluid, said vertical tank further comprising velocity regulating means disposed in said tank for increasing the velocity of said carrier fluid after it is introduced into said tank, and then decreasing the velocity of said carrier fluid prior to reaching said overflow means.

20 Claims, 3 Drawing Figures

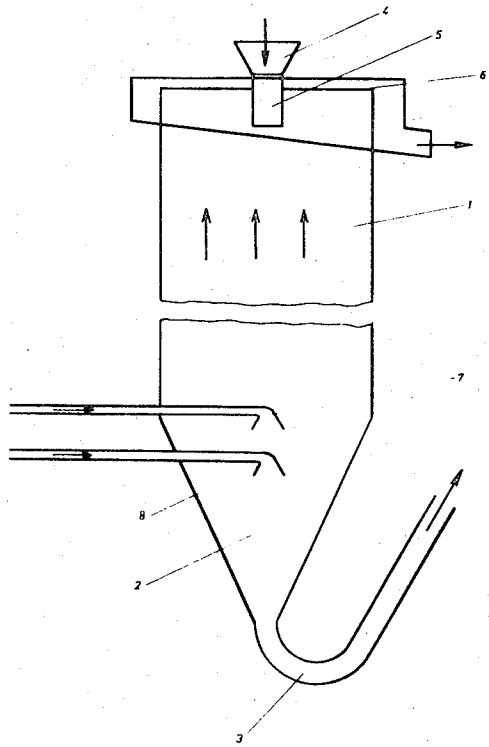
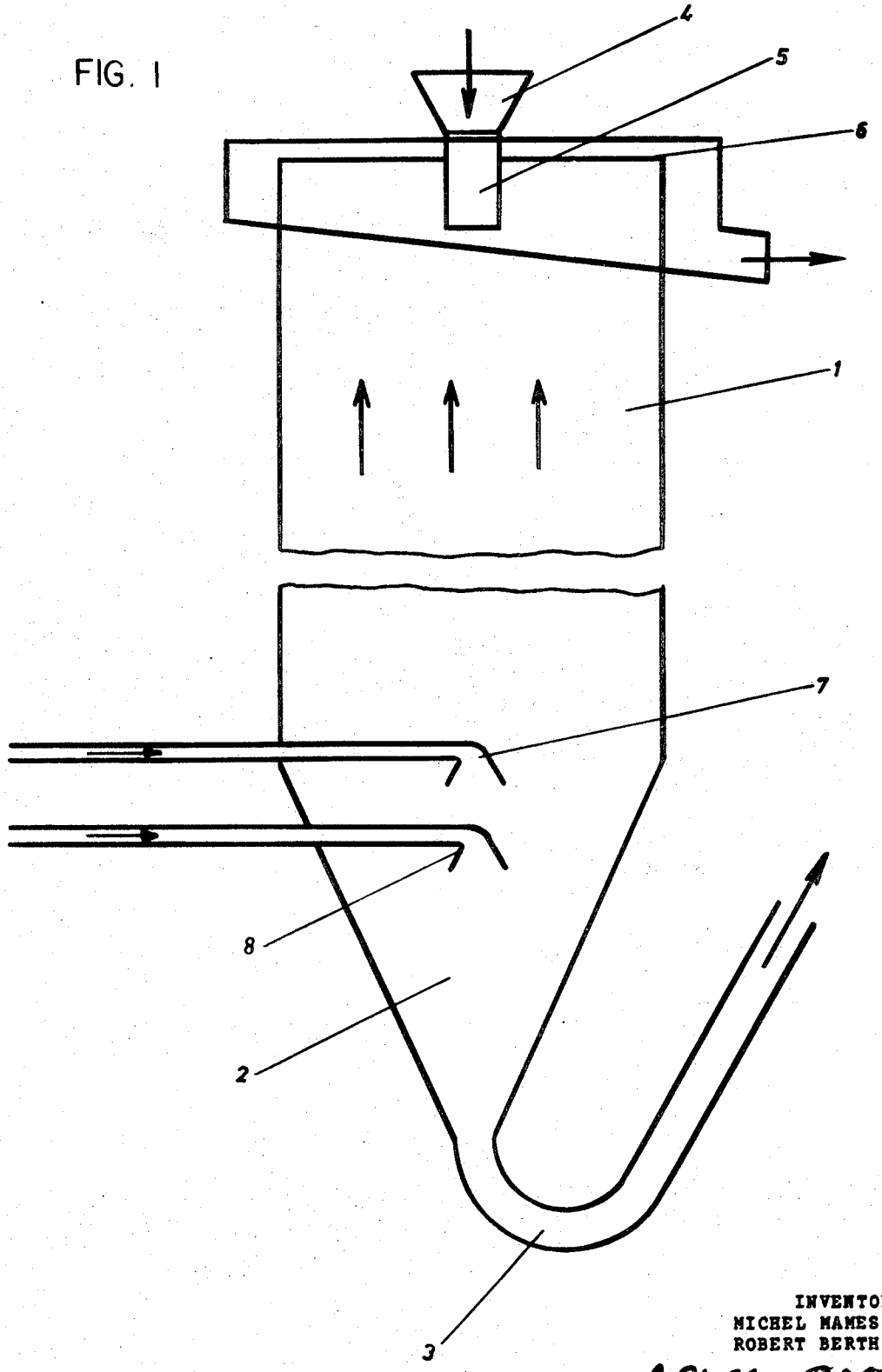


FIG. 1

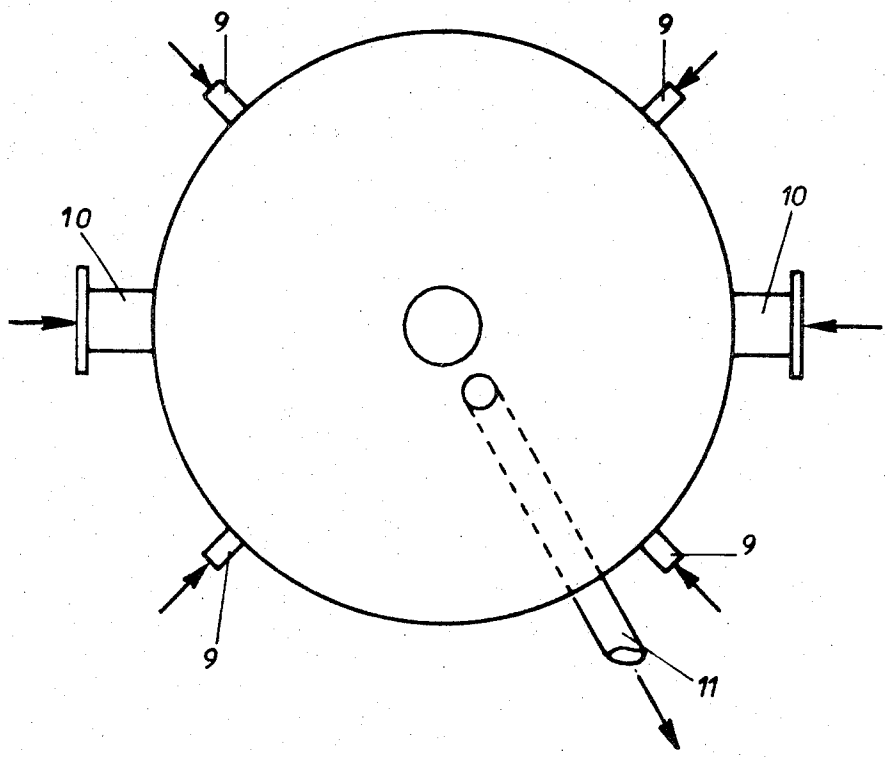


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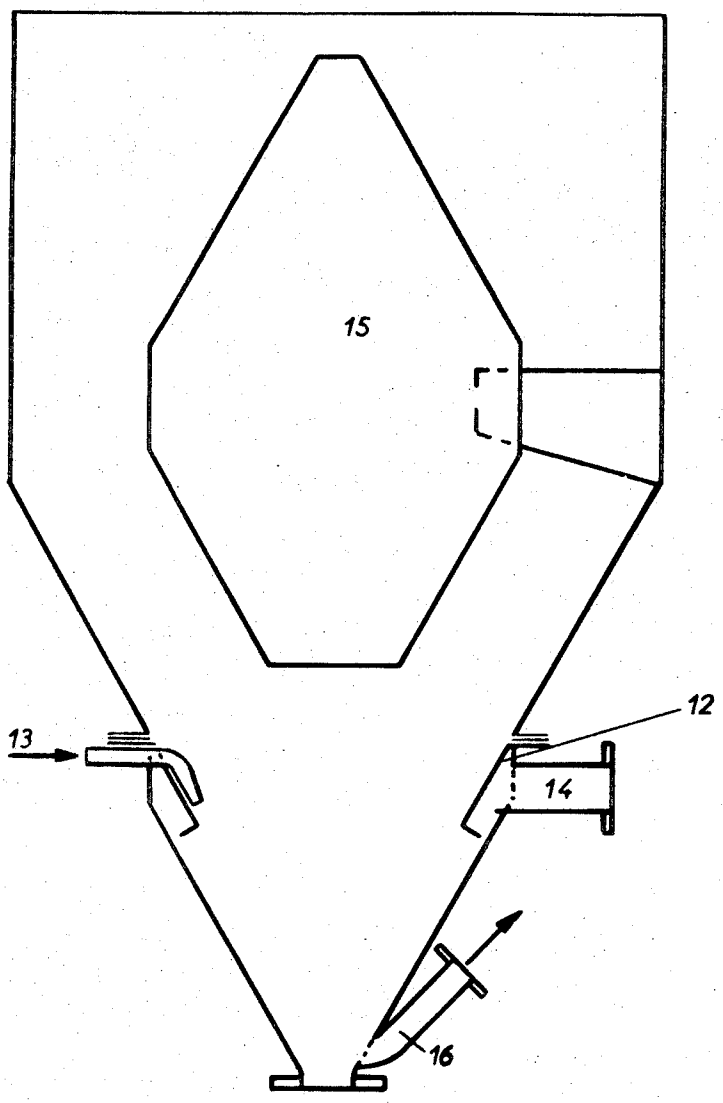
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FIG. 2



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FIG. 3



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FLOTATION OF COARSE PARTICLES

This application is a continuation of application Ser. No. 640,670, filed May 23, 1967, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to the selective flotation of coarsely ground ores, particularly ores having a particle size larger than about 28 mesh (Tyler sieve).

Froth flotation, a conventional technique for the separation of solids, is generally performed in the following manner. The ore is first comminuted to sufficiently liberate the desired components; and this step often also separates out substances normally deleterious to flotation, such as finely divided insoluble clay-like impurities. The thus prepared ore is then suspended in either water or an aqueous solution saturated with respect to the soluble constituents of the ore, thereby forming a pulp. The latter is conditioned by the successive or simultaneous addition of reagents comprising: collectors which selectively film particles enriched in certain components of the ore; depressants which prevent or considerably reduce the detrimental effects of various factors, particularly those effects arising from clay-like impurities; and frothing agents which facilitate the dispersion of the air bubbles and the formation of froths which elevate particles selectively filmed by the collector. The conditioned pulp is then passed to a flotation cell wherein the particles collected on the surface by the froth are separated from the particles settled at the bottom of the cell.

According to the most widely used method, the flotation is performed with a pulp which flows in a substantially horizontal direction in a plurality of series-connected cells. Generally, the conditioned pulp is fed continuously into the first cell and the non-floated particles are continuously withdrawn from the last cell of the series. Each cell has the shape of a tank open at the top and is provided in its center with a device which functions as an agitator and as an air injector. This device provides thorough contact between the air bubbles and the ore particles and, in addition, promotes the circulation of the pulp from one cell to the next. The ore ordinarily treated in these cells is usually ground to a particle size lower than 28–20 mesh.

During the years, many other types of flotation machines have been described in the patent literature. For example, another type of stirrer-provided cell provides vertical countercurrent flow between the pulp and the air bubbles. In this cell, wherein the diameter thereof is smaller than the effective height, the pulp is introduced at the top where it is uniformly distributed by a rotating device, and air is introduced through another rotating distributor near the bottom of the cell to provide a fine dispersion of air bubbles. The pulp circulates either by gravity in a cascade arrangement of serially connected cells, or by the injection of air into the pipe which joins the bottom of one cell to the pulp distributor of the next cell.

In another known type of cell, there is no mechanical stirring device; instead, agitation is caused by introducing the mixture of air and pulp by various means such as: suction of air by the pulp in an injector working as a water aspirator pump; aeration under pressure wherein the air is also used to move the pulp; cyclones, etc.

Unfortunately, none of the aforementioned cells yields completely satisfactory results when used with a coarsely ground ore, i.e., a particle size of larger than about 28 mesh. Indeed, the flotation of large particles necessitates the conflicting requirements of greater aeration and weaker agitation than ordinary flotation. Such requirements cannot be satisfied by the aforementioned cells because the aeration intensity is directly related to the degree of agitation, increasing with an increase in agitation, and vice versa.

However, it must also be mentioned that there are cells in which aeration does not depend on stirring. For example, in so-called pneumatic cells aeration takes place, through an inclined porous bottom. In addition to the difficulties which are generally encountered when using a porous plate (plugging of the pores, rapid wear and so on), there has been found that the flow of a coarse particle pulp on a porous bottom is most delicate and gives rise to problems which are nearly insoluble in practice.

Still another type of flotation cell where aeration is not related to stirring is described in Canadian Pat. No. 694,547. These cells have the shape of columns, the length of which is at least six times their width. In these columns air under pressure is introduced at the bottom through a diffuser which forms fine bubbles; a pulp previously conditioned in a separate tank is fed at an intermediate zone; and a washing liquid enters at the upper portion. Preferably, the cross-sectional area of this upper section is reduced so as to increase the speed of the downward stream of washing liquid, thus improving the froth separation. These columns are used in the treatment of extremely fine particles, such as those having a size not higher than 65 mesh with more than 50 percent having a size lower than 270 mesh. Again, though, it has been found that such columns do not give satisfactory results when used for the flotation of coarse particles.

In view of the preceding discussion, it is clear that heretofore, certain drawbacks were encountered in the flotation of coarse particles, thereby detracting from the value of coarse flotation in those cases where relatively coarse comminution is sufficient to liberate the valuable components. Otherwise, by coarse flotation, there are several advantages, particularly a substantial reduction in the grinding costs, and the easier material-handling of the resulting products.

A principal object of this invention, therefore, is to provide an improved system for the flotation of coarse particles.

Upon further study of the specification and claims, other objects and advantages of the present invention will become apparent.

SUMMARY OF THE INVENTION

To attain the objects of this invention, the conditioned pulp is fed to the upper portion of a cell and is allowed to flow by gravity countercurrently to an ascending stream of carrier fluid introduced at the lower portion of the cell, the floated particles suspended in the carrier fluid being collected at the overflow level and the non-floated product being withdrawn at the bottom of the cell.

The carrier fluid employed in this invention is introduced at least partly as a quasi-homogeneous dispersion of very fine air bubbles in a liquid. In other words, this can be described as a discontinuous air phase sur-

rounded by a continuous liquid phase. It can be prepared, for example, by means of a pump, a device similar to a water aspirator pump or, still better, by a mechanical emulsifier such as those used in chemical industry to beat together two fluids in order to produce a state of extremely fine division. Taking into account the last-mentioned device, the carrier fluid will be called hereunder an emulsion, of air and liquid, it being understood that there is meant a quasi-homogeneous dispersion of air bubbles in a liquid, the physical aspect of which is analogous to that of an emulsion of two liquids.

By operating according to the process of this invention, the ideal requirements for the flotation of coarse particles are substantially met. There is little agitation of the pulp flowing slowly downwards by gravity,—being decelerated by the rising stream of carrier fluid. At the same time, aeration is adjustable over a wide range and can be made as strong as desired. Each individual particle of ore can thus move upwards carried by as many air bubbles as necessary in this type of flotation. In this connection, this process, in its more favorable aspect, is not a conventional froth flotation because there is no stable formation of a mineralized froth in which the air bubbles are collectively stabilized by the fine mineral particles. Accordingly, the structure of the coarse particles supported by bubbles, though very fragile and easily destroyed by the slightest impact, can rise quietly and easily with the help of the upward stream of carrier liquid.

To simplify matters, other aspects of this invention are described in the following paragraphs by specific reference to the treatment of a potash ore, sylvinite, but it must be understood that this invention can be similarly applied to other potash ores, or, in fact, to any ore in which it is possible to liberate the components by relatively coarse grinding.

The suitably comminuted sylvinite ore (the grinding being of the wet or dry type) consisting predominantly of particles larger than 28 mesh and preferably larger than 20–16 mesh is formed into a pulp with a brine saturated with respect to the soluble components of the sylvinite. This pulp is conditioned with conventional flotation reagents.

In the case of sylvinite ores, saturated and unsaturated aliphatic amines with 8–22 C atoms and/or their water soluble salts are mostly used as collectors, starch and its derivatives, proteins, cellulosic products are known as depressants and various oils or alcohols are widely used as frothing agents.

The conditioned pulp is introduced at the upper region of a cell, and generally at the vertical axis thereof. The introduction of pulp should be conducted so as to prevent or considerably reduce turbulence at the upper zone of the cell. For this purpose, it is advantageous to introduce the pulp by gravity, the particles being thus only subjected to gravity at the time they are fed into the cell. The pulp feeding device discharges preferably at a short distance under the overflow level, for example, about 1 to 50, preferably 10 to 20 cm. This distance is an important factor in the efficiency of separation. It has been observed that for a cell of a given height, the yield increases when this distance decreases. Obviously, though, this increase in yield is obtained at the expense of a less pure concentrate. Conversely, when this distance is increased, the yield decreases but a purer concentrate is obtained. This distance can then be adjusted according to the treated ore and to the desired results.

The pulp introduced in the cell should preferably contain a large quantity of solids, for example, about 45–85 percent by weight and preferably about 60–70 percent. It has been found that an excess of brine creates too many whirlpools at the surface and modifies the upward velocity of the ascending stream of brine. If the conditioning of the ore should take place in the presence of a larger quantity of brine, the pulp should be thickened before it is introduced in the cell by using a thickener or the like.

At the lower part of the cell, the emulsion of brine and air is introduced by a fixed distributor which is designed to avoid turbulence as much as possible, particularly to avoid eddy currents at the overflow level of the cell. This brine-air emulsion can be introduced anywhere in the cross-sectional plane of the cell, preferably near the vertical axis of the cell or at its periphery. It is preferred that the vertical distance between the brine-air distributor and the overflow level be higher than 75 cm, preferably higher than 100 cm in a cell in which there is treated an ore consisting predominantly of particles larger than 28 mesh.

It is also advantageous to provide the introduction of a supplementary quantity of brine as a separate stream in addition to the brine introduced as a mixture with air. This supplementary brine helps to create an ascending stream so that it overflows at the top of the cell. The upward linear velocity of this stream depends mostly on the nature and on the particle size of the treated ore. Thus, for instance, there has been found that for a sylvinite having a particle size not larger than 8 mesh, an upward velocity of 1–1.5 cm/sec. is perfectly suitable; for a larger particle size up to 6 and even 5 mesh, the velocity must be higher, ranging about 2 cm/sec.

The introduction of this supplementary brine is generally performed in the vicinity of the brine-air distributor, i.e., at the lower part of the cell and, preferably, near its axis or at its periphery. As is the case of the brine-air emulsion, the device for distributing supplementary brine must create as little agitation as possible in the cell so that no eddy currents should reach the overflow level. Further, in this connection, the amount of supplementary brine fed to the cell can represent about 0 to 70 percent by volume of the total carrier fluid.

The introduction of brine and air-brine can be conducted with distribution nozzles which discharge into the cell at the same or different levels. Preferably, the nozzles are directed towards the lower part of the cell so as to prevent the formation of any turbulence which might be propagated to the surface. There can, for example, be provided two nozzles, one for the air-brine and one for the supplementary brine, with their discharge openings one above the other, substantially on the axis of the cell. Alternatively, there can also be provided, at the periphery of the cell, two series of nozzles for air-brine and supplementary brine, the nozzles of each series being either superimposed one above the other, or alternating on a same level. The nozzles are placed all around the cell or at a plurality of points

preferably disposed symmetrically on the periphery of the cell in order to provide as uniform a feed as possible.

According to a particularly advantageous embodiment, the supplementary brine is introduced all around the cell by a distributing device which prevents or reduces the whirlpools, and the emulsion is fed at a slightly higher level. The distributing device preferably comprises a distributing sheath placed around the cell and communicating with the latter through openings provided in the wall, these openings being optionally provided with baffle elements or deflectors which prevent excessive agitation at the brine feed. Another distributing system comprises, for example, discharge pipe (or pipes) carrying the brine under a deflector which is tied by its higher portion to the wall of the cell and which forms a kind of skirt inside the cell. The agitation created at the opening of the pipe (or pipes) is damped by the deflector. Thereby a quiescent flow of brine is discharged from the lower part of the deflector and enters the cell.

Along the path of the sylvinite particles in the cell, the air bubbles brought by the air-brine emulsion attach themselves to the particles of potassium chloride which have been selectively filmed by the collector and, with the help of the ascending stream of brine, carry these particles to the top of the cell in a continuous movement without any shock which might destroy the fragile structure of particles and bubbles. There is collected by overflow at the top of the cell the large particles of potassium chloride suspended in the brine, said particles being thereafter separated by any suitable means such as screening. The tailings, which contain substantially all the sodium chloride, are withdrawn at the bottom of the cell. The separation is such that a single pass through one cell gives tailings which are substantially free of liberated potassium chloride. However, these tailings or their coarser fractions often contain an important quantity of non-liberated KCl in the form of middlings which must be reground before being introduced into a standard flotation. The potassium chloride remaining in these tailings can also be recovered by a dissolving-crystallizing technique.

Another preferred embodiment of this invention comprises the use of a cell having the shape of a vertical tank with a horizontal cross-section of any form but preferably of a simple form such as circular, rectangular or square. This tank terminates at the lower portion by a narrower part, for example, of conical or pyramidal shape.

It is possible, if necessary, to vary the upward velocity of the carrier liquid at various levels in the cell without modifying the brine delivery or the overflow velocity. For this purpose, there is provided in the cell a shaped obstacle which reduces the free cross-sectional area for flow of carrier for a specific height. Preferably, this obstacle has an enlarged portion between two portions which become thinner towards the extremities so that the velocity of the ascending stream increases first progressively to a maximum value, then decreases progressively without creating any substantial agitation. Thus, the obstacle may be constructed as two inverted cones joined either directly by their base or by cylindrical part; it may also have an ovoid shape or any analogous form.

Owing to the presence of this obstacle which progressively increases the vertical velocity for a certain height of the path of the carrier liquid, it is possible to recapture, without destroying the fragile structure of bubbles on the particles to be floated, the largest particles of KCl which might otherwise fall and settle at the bottom of the cell. According to the nature and the particle size of the treated ore, there can be used, for example, an obstacle which increases the velocity of the carrier stream up to 3 times the overflow velocity.

By operating according to the process of this invention, the pulp feeding rate and, therefore, the output of the cell, is proportional to the horizontal cross-sectional area of the cell at the overflow level and does not substantially depend on the height of the cell. As a matter of fact, the "effective" height of the cell, i.e., the height in which the particle separation takes place, is relatively low and, for a given ore, varies but little with the output of the cell. Nevertheless, the distance between the point of introduction of the emulsion and the overflow level should preferably be at least 1.5 times the "effective" height to reduce the risks of turbulence at the surface due to the feeding of emulsion and/or make-up brine.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 of the attached drawing is schematic elevation of a preferred cell design of this invention.

FIG. 2 is a top plan view of a cell design of this invention showing symmetrically disposed inlets for the introduction of brine and air-brine.

FIG. 3 is schematic elevation of another preferred cell design of this invention showing distributing systems of brine and air-brine together with a shaped obstacle.

DETAILED DESCRIPTION OF THE DRAWING

An experimental cell is shown schematically on the accompanying drawing. The upper part **1** of the cell is cylindrical. The bottom **2** is in the shape of a cone being terminated at the lowermost portion thereof by a J-shaped pipe **3**. A frustoconical hopper **4** affixed at the narrow portion thereof by pipe **5** is used to introduce pulp below the overflow level **6** of the cell. A nozzle **7** for distributing the air-brine is provided at the bottom of the cylindrical portion **1**, and at a slightly lower level is placed a distributing device **8** for supplementary brine.

The experimental cell has a diameter of 0.30 m., and the cylindrical part is 1.50 m. high. This cell was used to treat 3.5 tons of sylvinite with an average K_2O content of 20.1 percent, and having the following average particle size:

+ 8 mesh	3.1%
−8 + 10 mesh	40.5%
−10 + 14 mesh	42.9%
−14 + 20 mesh	11.2%
− 20 mesh	2.3%

The rate of introduction of brine was adjusted to such a value that the linear upward velocity of the stream was 1.5 cm/sec.

The potassium chloride concentrate collected at the overflow level was separated from the accompanying brine and dried. It contained 59.6% K_2O and had the following average particle size:

+8 mesh	0.9%
−8+ 10 mesh	36.4%
−10+ 14 mesh	46.1%
−14+ 20 mesh	14.5%
− 20 mesh	2.1%

The mesh size openings correspond to Tyler sieve sizes.

The K_2O yield of the operation (calculated as K_2O in the concentrate versus K_2O present in the treated ore) was 85 percent and the tailings withdrawn at the bottom of the cell contained only 4.0 percent of K_2O.

To accomplish this flotation, the ore was treated with following flotation reagents : 100 g/t of starch as depressant, 200 g/t of stearylamine acetate as collector and 200 g/t of fine oil as frothing agent. In this cell the rate of introduction of the pulp has been adjusted to 270 kg/h and there has been withdrawn 90 kg/h of concentrate.

FIG. 2 of the accompanying drawing is a plan view of a cell according to the invention. In this cell the air-brine emulsion is introduced by four nozzles **9** distributed symmetrically at the periphery of the cell and supplementary brine is fed through nozzles **10**. The tailings are with-drawn through pipe **11**, the pulp introduction and withdrawal systems not being shown on this simplified drawing.

FIG. 3 of the accompanying drawing is a schematic elevation of another cell according to the invention. On this figure **12** represents a deflector-skirt. Brine is fed through line **14** behind this element and emulsion is fed close to this element, but over it, through line **13**. An obstacle **15** having the shape of two inverted cones joined by a cylindrical part is used to vary the upward velocity of the carrier stream. The tailings are withdrawn through pipe **16**.

The preceding examples can be repeated with similar success by substituting the generically and specifically described reactants and operating conditions of this invention for those used in the preceding examples.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions. Consequently, such changes and modifications are properly, equitably, and intended to be, within the full range of equivalence of the following claims.

We claim:

1. A coarse flotation process comprising the steps of:

a. feeding a conditioned pulp containing about 45–85 percent solids of which a major portion is at least as large as +28 mesh to an upper zone of a flotation cell at a level below the overflow level so as to prevent or considerably reduce turbulence at the upper zone of the cell;

b. feeding a carrier fluid consisting essentially of an emulsion of air and liquid to a bottom zone only of said cell at a rate and in such a manner as to substantially avoid turbulence, whereby the very fragile and easily destroyed structure of the coarse particles supported by bubbles can rise;

c. effecting countercurrent flow of said pulp and said carrier fluid in said cell;

d. withdrawing floated particles as overflow from the top of said cell, said floated particles comprising a fraction of said major portion; and

e. withdrawing tailings from the bottom of said cell.

2. A process as defined by claim **1** wherein the pulp contains 60–70 percent solids.

3. A process as defined by claim **2** wherein the pulp contains particles of which a major portion is larger than 20–16 mesh.

4. A process as defined by claim **3** wherein the pulp is fed at 10–20 cm. below the overflow level.

5. A process as defined by claim **1** wherein the pulp contains particles of which a major portion is larger than 20–16 mesh.

6. A process as defined by claim **1** wherein the pulp is fed at 1–50 cm. below the overflow level.

7. A process as defined by claim **1** further comprising feeding a supplementary quantity of the carrier liquid in a separate stream adjacent to the feeding of said carrier fluid.

8. A process as defined by claim **7** wherein the carrier fluid is introduced at a zone substantially along the vertical axis of said flotation cell.

9. A process as defined by claim **8** wherein the carrier liquid is introduced at zone along the vertical axis of said flotation cell below the point where carrier fluid is introduced.

10. A process as defined by claim **7** wherein the carrier liquid is introduced around the periphery of said flotation cell.

11. A process as defined by claim **1** wherein the pulp comprises a saturated suspension of 60–70 percent by weight of solid sylvinite ore having a major portion of larger than 20–16 mesh particles.

12. A process as defined by claim **11** further comprising feeding a supplementary quantity of brine in a separate stream adjacent to the feeding of said carrier fluid.

13. A process as defined by claim **12** wherein the carrier fluid has a linear vertical upward velocity of at least 1 cm/sec.

14. A process as defined by claim **13** wherein the pulp is fed at 10–20 cm. below the overflow level.

15. A process as defined by claim **1** wherein the pulp is fed at 10–20 cm. below the overflow level.

16. A process as defined by claim **15** wherein the vertical distance between the point of introduction of the carrier fluid and the overflow level is more than 75 cm.

17. A process as defined by claim **1** wherein the velocity of the carrier fluid is increased as it rises in the flotation cell and then is decreased before it overflows.

18. A process as defined by claim **1** wherein the distance between the point of introduction of the emulsion and the overflow level is at least 1.5 times the effective height of the cell in which particle separation takes place.

19. A process as defined by claim **1** wherein the conditioned pulp is sylvinite, the carrier fluid comprises brine, and the upward velocity of the brine is about 1–2 cm/sec.

20. A coarse flotation process comprising the steps of:

a. feeding a conditioned pulp of which a major portion is at least as large as +28 mesh to an upper zone of a flotation cell at a level below the overflow level in such a solids concentration and in such a manner so as to prevent or considerably reduce turbulence at the upper zone of the cell;

b. feeding a carrier fluid consisting essentially of an emulsion of air and liquid to a bottom zone only of

said cell at a rate and in such a manner as to substantially avoid turbulence, whereby the very fragile and easily destroyed structure of the coarse particles supported by bubbles can rise;

c. effecting countercurrent flow of said pulp and said carrier fluid in said cell;

d. withdrawing floated particles as overflow from the top of said cell, said floated particles comprising a fraction of said major portion; and

e. withdrawing tailings from the bottom of said cell.

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